

Appln No. 10/735,148

Amdt date November 11, 2005

Reply to Office action of September 8, 2005

Claims 1, 2, 5-10 and 13 were rejected under 35 U.S.C. § 102 as anticipated by disclosures in a paper by Choi-Yim et al. According to the Examiner, the prior art composite materials in the Choi paper, for example, are made by a method in accordance with that recited in claim 1. This is incorrect since the Choi-Yim composite material does not have particles formed in situ in the matrix.

When particles are formed in situ in an amorphous matrix, as described in this application, there is first a molten alloy having a composition different from either the amorphous matrix or the particles. As this molten alloy is cooled more rapidly than a critical cooling rate (which is a characteristic of the alloys) particles of one composition precipitate throughout the melt by homogeneous nucleation. As the melt is further cooled, the remaining liquid essentially becomes more and more viscous to become an amorphous solid matrix (a metallic glass) in which the precipitated particles are embedded. This technique for forming a composite was not known before this invention and no metallic composites with crystalline metal particles had been formed in situ in an amorphous matrix.

So far as is known, prior composites of metal in an amorphous metal matrix have been made by either of two techniques, one of which is mentioned in the Choi-Yim paper. The first technique has been to have solid "particles" which may be in the form of wires or an aggregate of more three dimensional particles or grains. A liquid alloy which is capable of forming an amorphous matrix is infiltrated into the void spaces between the pre-existing solid particles. When this liquid metal cools and freezes, it forms an amorphous matrix embedding the mass of particles in which it was infiltrated.

The other technique is to make a mixture, slurry, or "slush" of preexisting particles and an alloy that can be cooled to remain amorphous. These particles have a higher melting point than the glass-forming alloy and have little or no solubility in the glass-forming alloy. The particles mixed with the glass forming alloy may be heated to melt the alloy or the mixture may be formed by stirring particles into an already molten alloy. In either case, when the molten alloy cools, the preexisting particles remain in an amorphous matrix. A feature of this technique is that such a "slush" mixture can essentially be cast to a desired size or shape. This is the

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technique described in the Choi-Yim paper in the section entitled Experimental Methods, referred to by the Examiner.

Choi-Yim describes the technique as follows:

"Ingots of the [matrix "Vit 106"] alloy were prepared . . . subsequently a mixture of the prealloyed Vit 106 and the particles was induction melted . . . Volume fractions of particles range between 5 and 20 % . . . The composite ingots were remelted at temperatures ranging from 850 and 1100°C . . . and then injected through a nozzle into a copper mold. . . ."

This resulted in an object in which preexisting particles were embedded in an amorphous matrix of the Vit 106 alloy. Some of the particles studied were metal carbides and would not be material to anything in this application. Particles of metallic tungsten were also used to make such a composite. These preexisting tungsten particles were not significantly dissolved in the matrix alloy and formed in situ in the matrix.

As Choi-Yim states:

"Interfaces between Vit 106 and W particles were also studied. . . . no reaction layer can be detected. . . . At the interface between the matrix and the W particle, crystals with a diameter of 50-100 nm have formed. . . . the compositions of these crystals are close to the average matrix composition. . . In the case of the Ta and W particulate, the metals are simply dissolved into the liquid matrix during processing. . . . At the W/Vit 106 interface, in contrast, crystallization of matrix material is observed. Nanocrystals with a composition not far from the matrix composition have formed during the cooling process. This can be either a result of heterogeneous nucleation at the W/Vit 106 interface or the glass forming ability of the matrix in the vicinity of the tungsten can be reduced due to the enhanced W concentration (in the W concentration gradient) close to the particle compared to the small tungsten concentration in most of the matrix of less than 0.5 at.%."

This demonstrates that a very small amount of the preexisting tungsten particles dissolved into the liquid which became the amorphous matrix. Apparently the tungsten dissolved from the surface of the particles resulted in trivial crystallization at the particle/matrix interface. Although a trivial amount of the tungsten dissolved into the liquid matrix alloy, the particles remained in tact and were not formed in situ. Thus, the techniques described by Choi-Yim are not the same as described in this application.

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Claim 1 (and others) was also rejected under 35 U.S.C. § 103 as being unpatentable over a patent issued to Lin et al. and in a separately stated rejection under section 103 as being unpatentable over a paper by Dandliker et al. As the Examiner has pointed out with respect to both of these bases for rejection, Applicant's claims are in the nature of a "product-by-process claim." It is stated that, in that situation, the burden falls to applicant to show that any process steps in the claim result in a product materially different from that disclosed in the prior art.

Enclosed herewith is a Declaration under 37 C.F.R. § 1.132 of Dr. William L. Johnson, a Professor at California Institute of Technology, whose career has concentrated on study and development of amorphous metal compositions, processes and products. Dr. Johnson is one of the co-inventors of the invention described and claimed in this application as well as several other patents and applications concerning amorphous metals. Dr. Johnson is a co-author or co-inventor on each of the references referred to by the examiner. As pointed out in this Declaration, a composite material produced by a technique as described in the application is remarkably different from any other known composite.

It has been discovered that such a composite not only has ductility, which is not present in an unreinforced amorphous metal, but also that very much thicker sections of composite can be made than is possible with composites made by infiltration, for example. This is because the critical cooling rate for a composite made by in situ precipitation of particles is at least an order of magnitude less than the critical cooling rate for a glass forming alloy having the same composition as the matrix.

Other composites made by infiltration may sometimes be made in somewhat thicker sections than the glass-forming matrix alone, however, that increase is relatively minor and is attributed to a somewhat higher thermal conductivity of the embedded second phase in the amorphous matrix. Such an improvement would not occur if the thermal conductivity of the particles is less than the matrix. The effect in such prior composites is one of extracting heat faster, rather than decreasing the critical cooling rate. This is the magnitude of the effect that would be found in any of the composites mentioned in the references.

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The very large decrease in critical cooling rate obtained in applicants' composite products and consequent ability to cast much thicker objects would not be provided by nor suggested by anything in the Dandliker or Lin references, or in Choi-Yim, for that matter. Applicants' claimed composites with the second phase formed in situ are materially different from the composites described by Dandliker or Lin. The process recitations as well as the properties must be considered with respect to allowability of the claim.

We need to keep in mind Judge Rich's cogent analysis in *In Re Papesch*, 315 F.2d 381, 137 U.S.P.Q. 43, 51 (C.C.P.A. 1963),

From the standpoint of patent law, a compound and all of its properties are inseparable; they are one and the same thing. . . . the patentability of the thing does not depend on the similarity of its formula to that of another compound but of the similarity of the former compound to the latter. There is no basis in law for ignoring any property in making such a comparison. An assumed similarity based on a comparison of formulae must give way to evidence that the assumption is erroneous.

Applicants' claim 1 recites a product having an amorphous metal alloy as a substantially continuous matrix and a second ductile metal phase in the matrix which is formed in situ therein by crystallization from a molten alloy. This product is materially different from anything shown or suggested by the references. Dandliker describes only composite materials made by infiltrating liquid metal into a pre-existing bundle of metal wires or loose tungsten particles. These wires and particles are not formed in situ in the matrix by crystallization. The Dandliker paper even states that "dissolved reinforcement material is not a significant constituent of the crystals [found in the matrix]." (The paper speculates that such crystals are due to oxides in the melt.)

The Choi-Yim paper also discusses composites made with substantially insoluble tungsten particles which are not formed in situ in the matrix. The Lin reference has a catalog of possible materials which may be embedded into a matrix of amorphous metal. The reference states that "the fibers or particles selected should, of course, not react with or dissolve in the metal alloy forming the amorphous phase." Given those criteria, it would be impossible to form a second metal phase in situ. The Lin reference clearly teaches away from applicants' claimed

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invention. Because the second phase is formed in situ, it is, in fact, different from anything that can be produced according to the teachings of Choi-Yim, Lin or Dandliker.

It is interesting to note that recently, subsequent to filing this application, it has been found that tungsten particles can be precipitated in a glass-forming alloy matrix. When a mixture of tungsten particles and Vit 106 alloy is heated to quite elevated temperatures, appreciable tungsten may be dissolved in the matrix alloy. For example, if heated to about 1500°C, as much as 15 at% tungsten may dissolve in the molten metal. More tungsten can be dissolved at higher temperatures. Upon cooling the molten metal, the tungsten precipitates and forms a crystalline second phase in situ in an amorphous matrix. At most a trivial amount of such precipitation may be present in the Choi-Yim materials, which are described as having nanocrystals formed near the interface of the pre-existing tungsten particles and the Vit 106 matrix. The Choi-Yim samples were melted at 850 - 1100°C where tungsten solubility is quite low. It was not known at that time that tungsten could be precipitated after higher temperature dissolving.

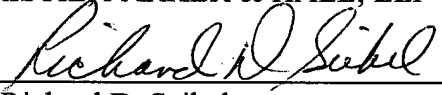
It is also an interesting observation, which may not be material to this application, that tungsten is not generally useful as a ductile reinforcement for an amorphous metal composite. Tungsten is not very ductile. More significantly, tungsten has a much higher modulus of elasticity than the matrix materials, and a low modulus material is needed. One of the few applications for a tungsten composite is as a high velocity penetrator, and there the composite is made by infiltration of liquid glass-forming alloy into a permeable mass of tungsten (either wires or a "sponge" of tungsten).

As stated in the accompanying Declaration of Dr. Johnson, the composite formed by in situ precipitation of a ductile metal phase in an amorphous matrix is different from composites made by infiltration or casting of the glass-forming alloy around pre-existing particles. Claim 1, which recites forming a second ductile metal phase in situ in the matrix by crystallization from a molten alloy, should be allowed. Of course, the claims dependent from it should also be allowed.

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All of the claims in this application were rejected for alleged double patenting. Enclosed herewith is a Terminal Disclaimer which obviates this rejection. Reconsideration, reexamination and allowance of this application are respectfully requested.

Respectfully submitted,
CHRISTIE, PARKER & HALE, LLP

By 
Richard D. Seibel
Reg. No. 22,134
626/795-9900

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